Electric Reaction Towers
Re-thinking Endothermic Processes for a Net-Zero Future

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The chemical industry faces unprecedented pressure to reduce its carbon footprint while meeting growing global demand. As a major contributor to greenhouse gas emissions, accounting for approximately 7% of global carbon release, the sector plays a crucial role in achieving net-zero goals. This challenge is further compounded by projections suggesting that demand for chemicals could increase up to four-fold by 2050, and by the sector's role in producing several raw materials for other industries.

Within this context, endothermic reactors are of particular concern. The production of ethylene, propylene, and hydrogen alone accounts for around 3.6% of global CO_2 emissions, representing over half of the chemical industry's total release. This situation underscores the need for alternatives in reactor design and operation.

To address these challenges, we introduce novel decarbonized process schemes and unit operations. The research centers around the development of Electric Reaction Towers (ERTs), a novel reactor configuration designed to ensure consistent product composition despite intense process fluctuations, such as those associated with Variable Renewable Energy (VRE). This is achieved by creating Custom Non-linear Heat Profiles (CNHPs) that maintain the key dimensionless groups of the system under dynamic conditions.

We present the concept of ERTs, explore their key principles, and the intuition behind their design. Additionally, we introduce Modular Reaction Towers (MRTs), which retain the benefits of handling fluctuations while addressing the investment and logistical challenges of adopting electric reactors.

The research employs a combination of Dimensional Analysis, Process Simulations, and Computational Fluid Dynamics (CFD) to evaluate these novel designs. Using ethylene production as a case study, we demonstrate that ERTs can enhance output by up to 4.2 times compared to state-of-the-art industrial designs.

The study further explores several additional concepts: Intermediate Cooling Zones (ICZs) and their potential to optimize complex reaction systems; the application of MRTs in the decentralized production of liquid hydrocarbons from shale gas to reduce flaring; and TurboQuenching, a novel approach to rapidly cool reaction products without a cooling agent while co-producing power. Finally, we discuss the broader implications of these innovations for the chemical industry's transition to more sustainable and efficient production methods.

By fundamentally re-thinking reactor design, this research contributes to the development of more efficient and sustainable production methods in the chemical industry, supporting the transition to a Net-Zero future.